TECHNISCHE UNIVERSITÄT DRESDEN

Breadboard Design

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Outline

- Design of x-ray imaging geometry
- Components:
    - source
    - heater, furnace and sample (ASTRIUM)
    - detector (SSC, Scint-X)
- Development tests at TU Dresden:
    - verification of x-ray imaging scheme
- Discussion of design issues

Design Concept: Magnified X-Ray Projection Imaging

Microfocus source:
reduced brilliance compared to synchrotron radiation source!

High frame rate (high detected flux per pixel):

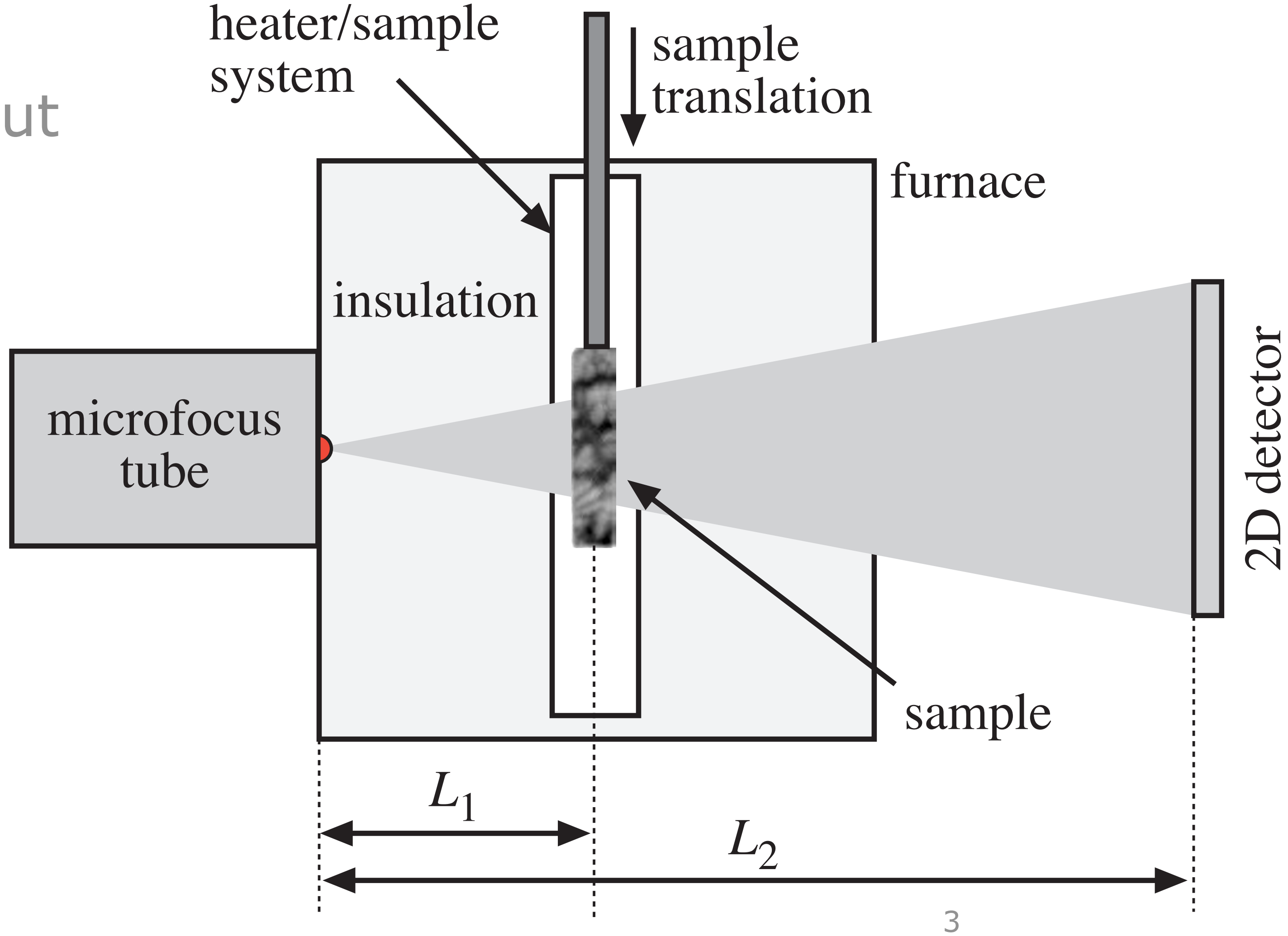
- high brilliance
- large solid angle of pixel
- efficient & high throughput detector

High spatial resolution:

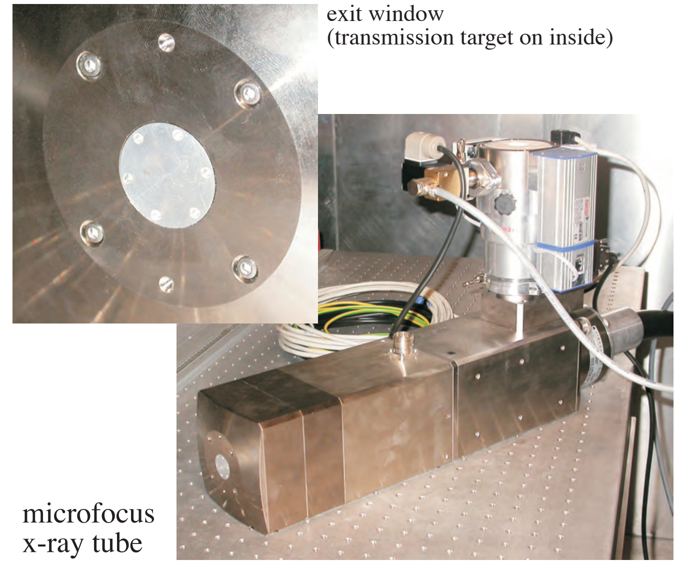
- small source size
- magnification

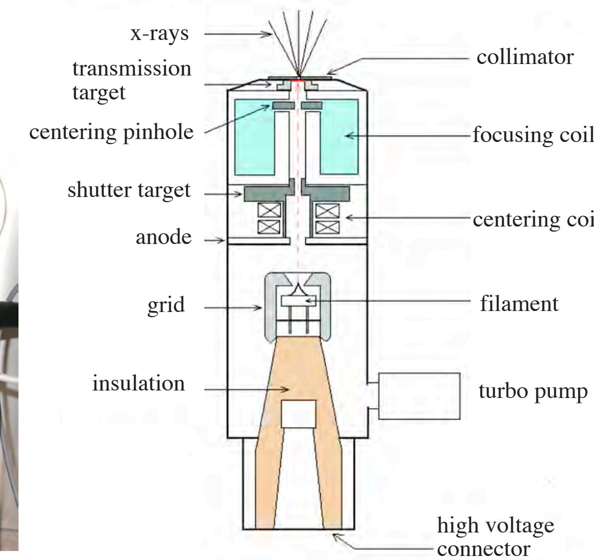
High contrast for AlCu:

- relevant spectral range: 9 to 60 keV



High Frame Rate





- high brilliance

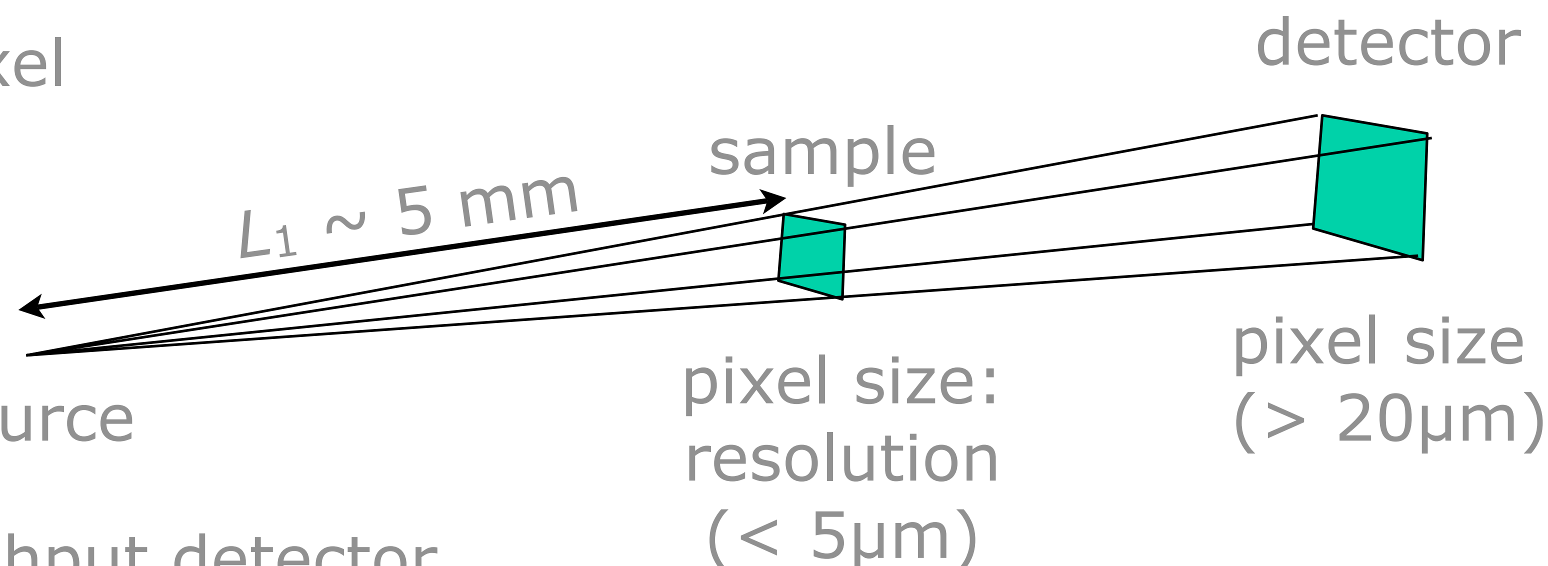
  many photons per

  - source size
  - solid angle

- large solid angle of pixel

  photons per pixel:

  $F \sim Br \cdot \Omega$



- efficient & high throughput detector
  - pixel size limited by efficiency (from below) and geometric constraints (from above)

- free beam path: minimize material in beam path (windows)

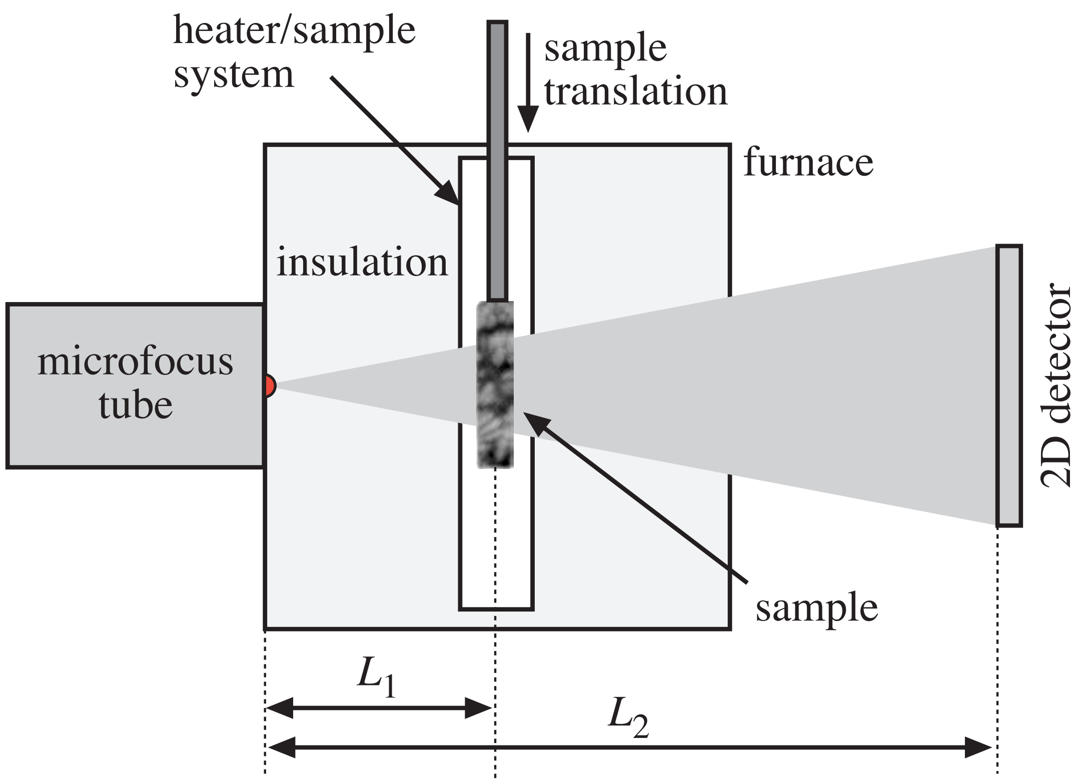
Spatial resolution requirement

resolution:

$$\xi = \sqrt{\xi_d^2 + \xi_D^2}, \quad \xi_d = \frac{M-1}{M} \cdot d, \quad \xi_D = \frac{1}{M} \cdot D$$

Influence of source size

Influence of detector pixel size



d: source size
D: detector pixel size

critical parameter:

source size!

$$\xi \approx 5\ \mu\text{m} \quad \Rightarrow \quad d \leq 3.5\ \mu\text{m}$$

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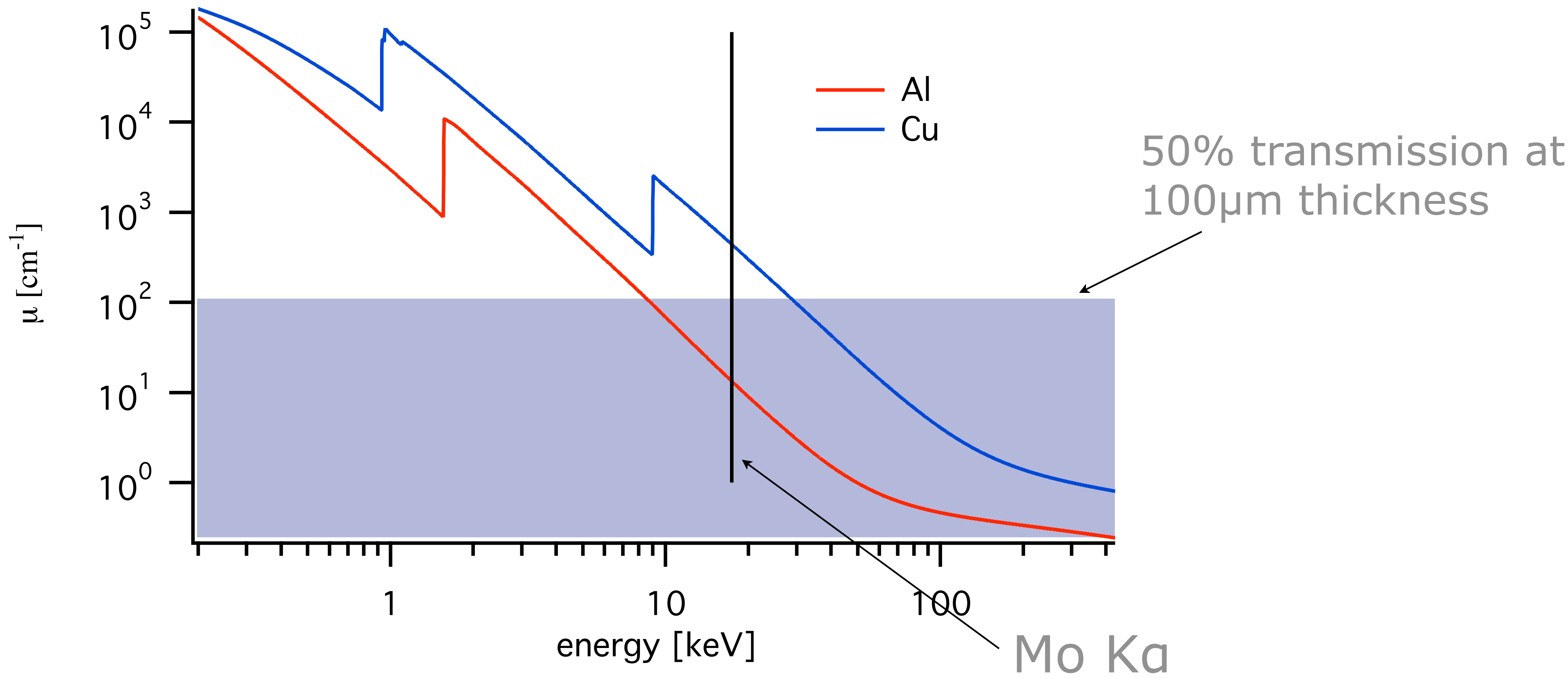
X-Ray Energy and Target Material



→ Molybdenum Target excited with 60kV well suited!

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X-ray Imaging Parameters

Source

source size	< 3.5 µm
power	3 W
acceleration Voltage	60 kW
target material	Mo
transmission target thickness	0.2 mm

Geometry

source-to-sample distance L_1	~ 5 mm
source-to-detector distance L_2	> 70 mm
magnification M	14x

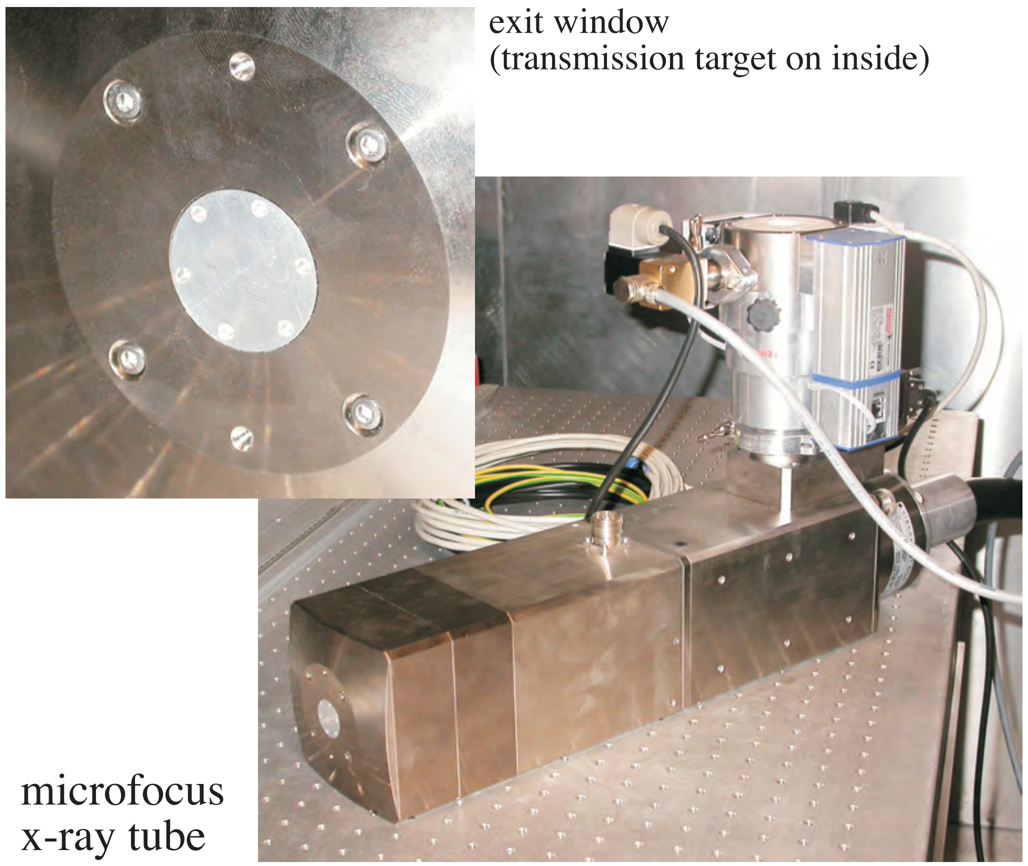
Detector

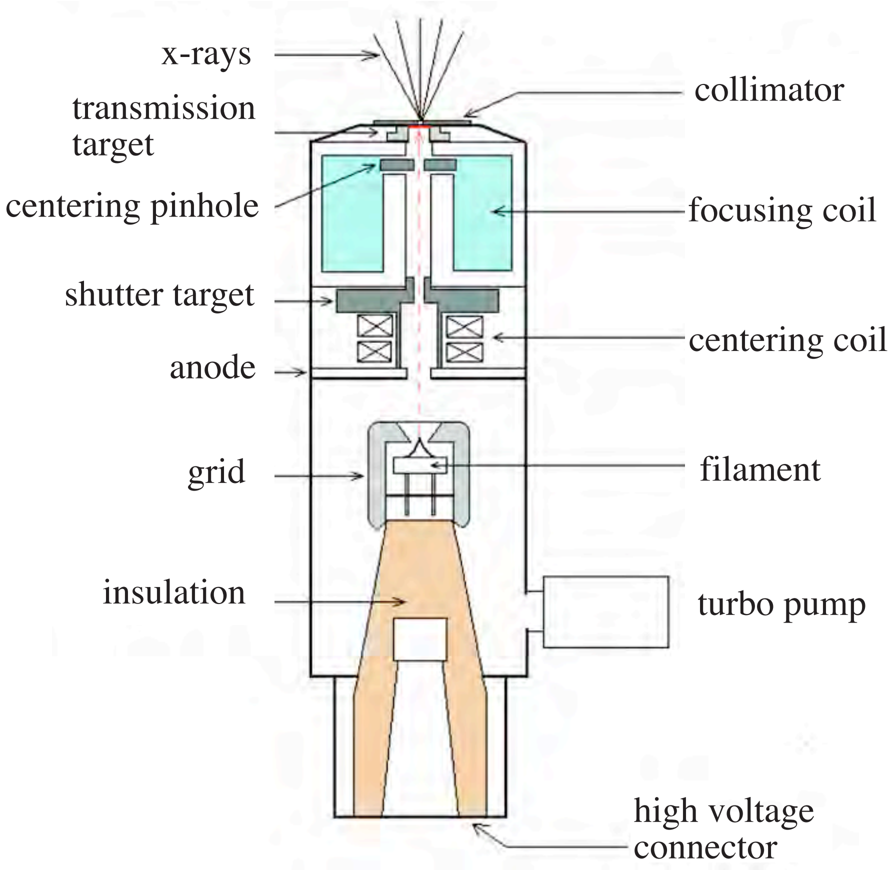
pixel size (effective)	~ 20 µm
size of field of view (in effective pixels)	2k x 1.3k
detective quantum efficiency	~ 50%
frame rate	> 3 Hz

Spatial resolution:

5 µm at sample

X-Ray Microfocus Tube

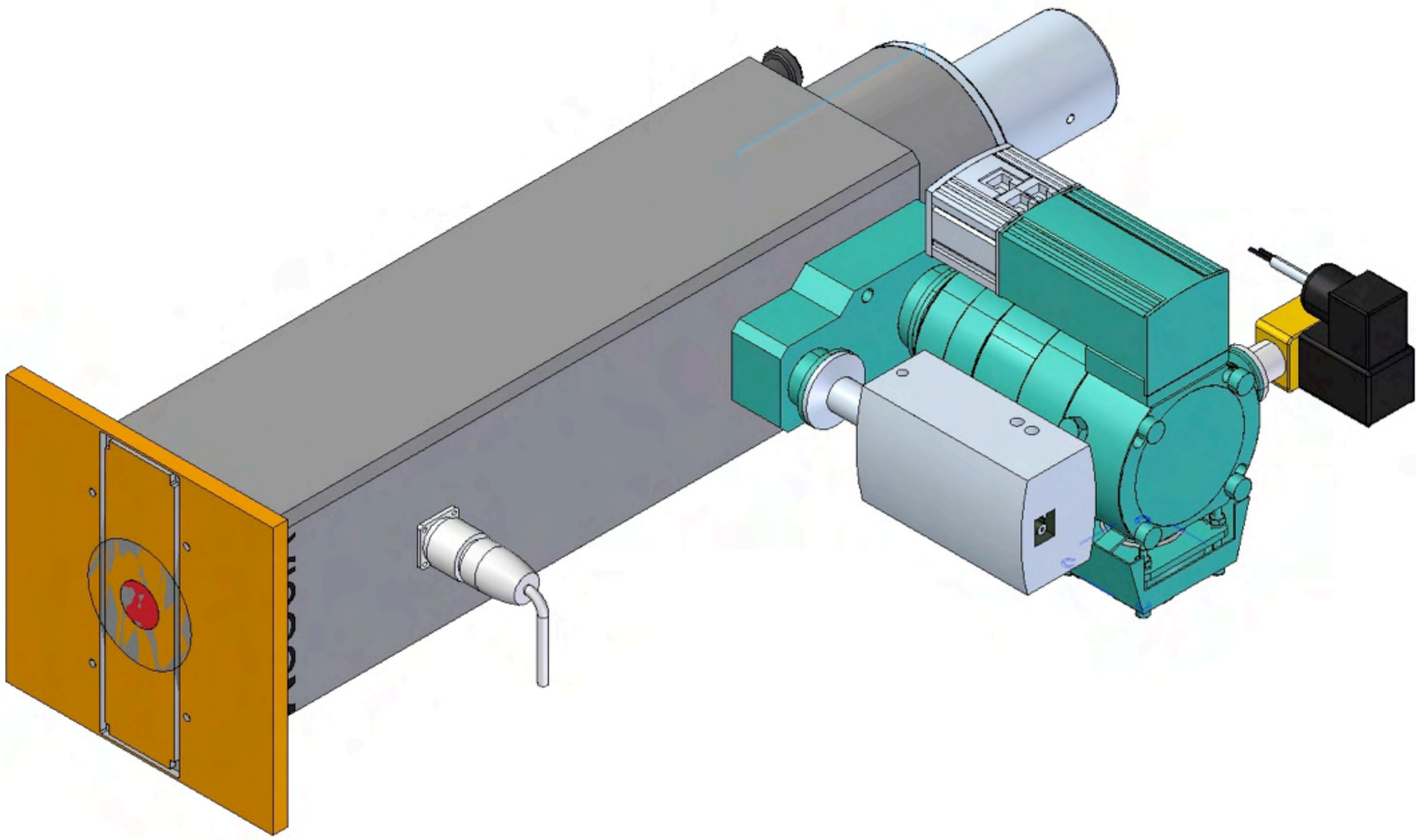




Properties:

- source size: $d < 3\mu m$ @ 3W ($U = 60$ kV, $I = 50$ µA)
- brilliance: verified by development test
- energy: Mo target on Al window (Kα: 17.4 keV, Kβ: 19.6 keV) bremsspectrum up to 60 keV for parameters above

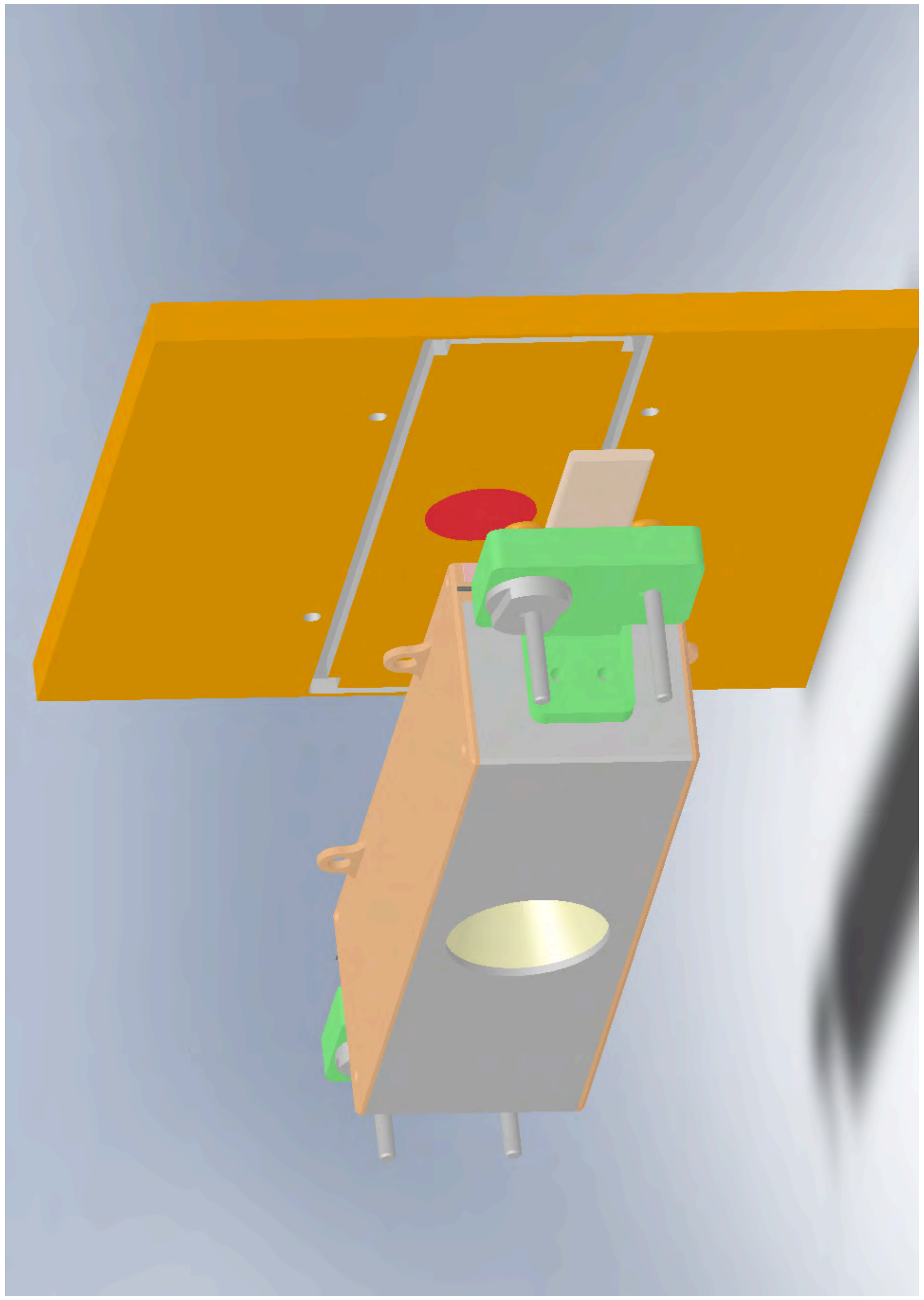
X-Ray Microfocus Tube

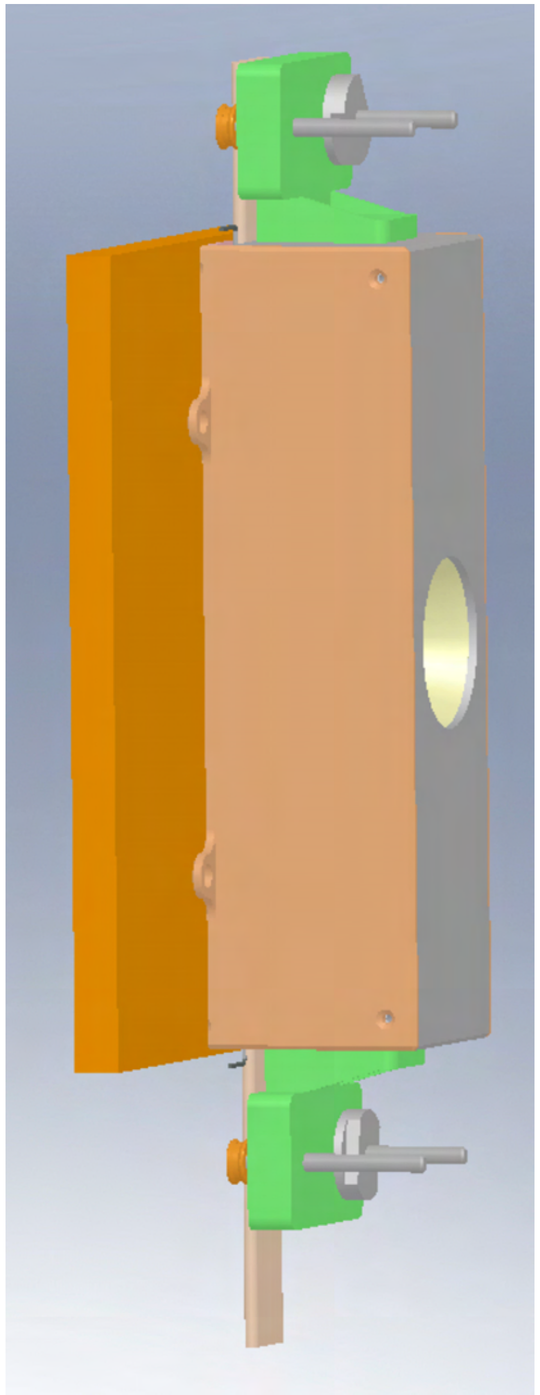


Technical modifications:

- cooled front plate (modified, cooling not shown), Al window
- fixation of sample/heater/furnace to front plate possible
- more compact: shorter design allows for compact setup
- design of front plate will be finalized after visit of Viscom at Astrium

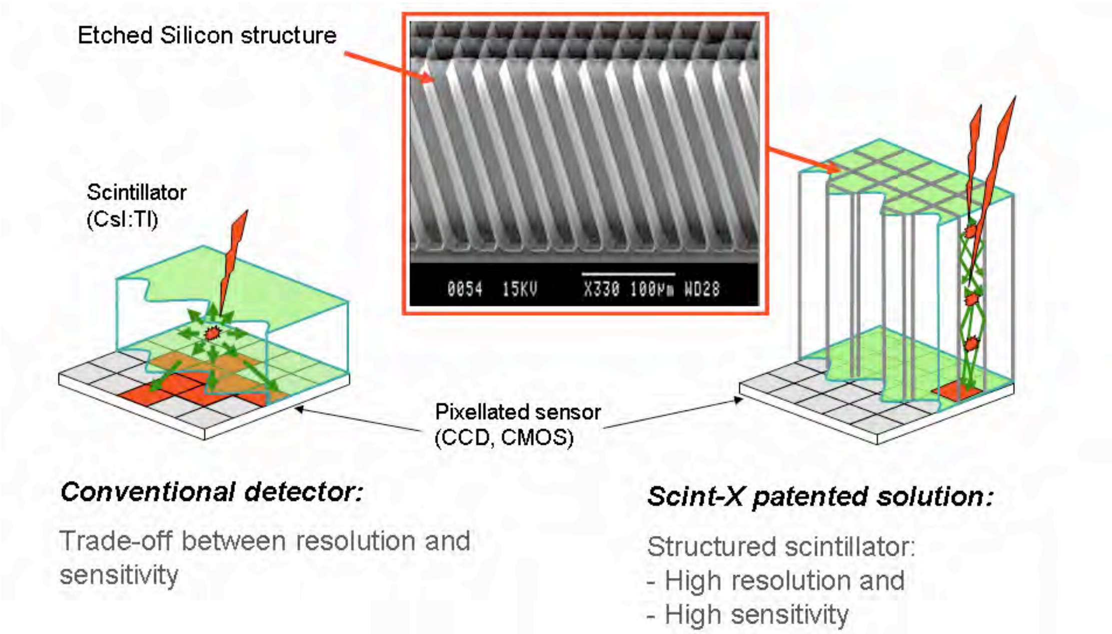
Sample, Heater, Furnace

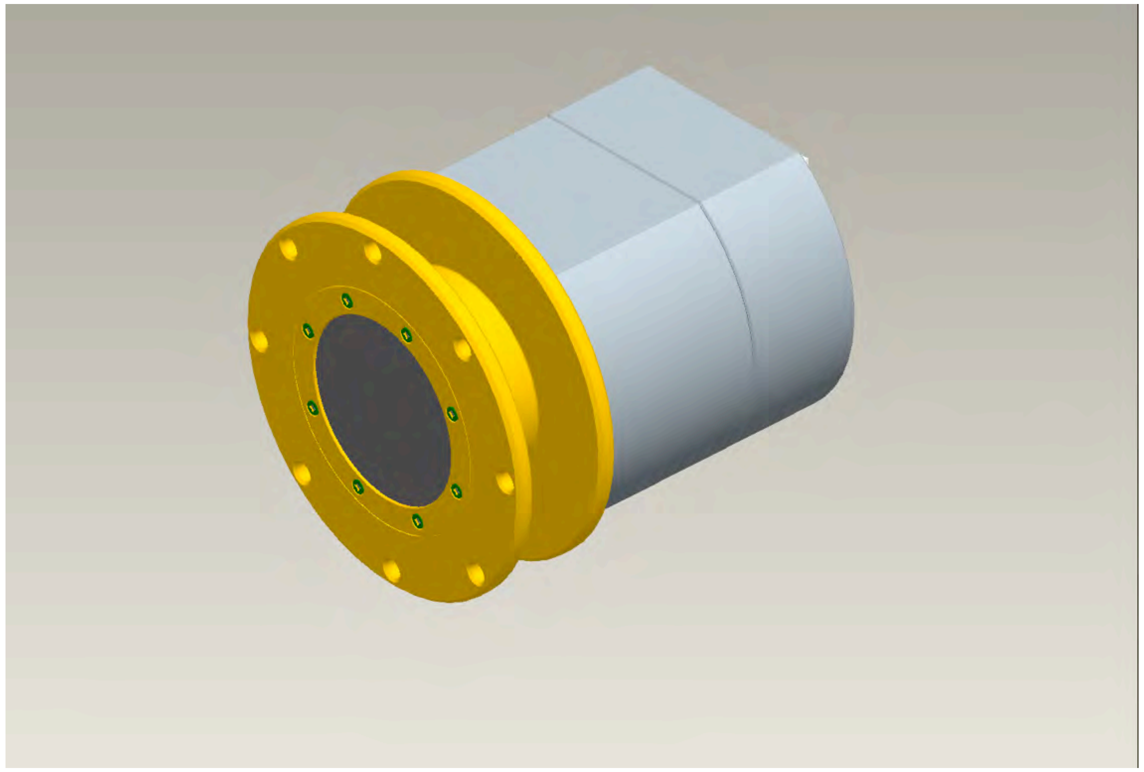




- Mounted to front plate of Source
- Details of updated design given by Astrium

Strategy for Detector





Our strategy:

increase spatial resolution at high quantum efficiency

→ structured scintillator matched to CCD pixel size (~ 20 µm)

→ short detector (no optic between scintillator and sensor chip)

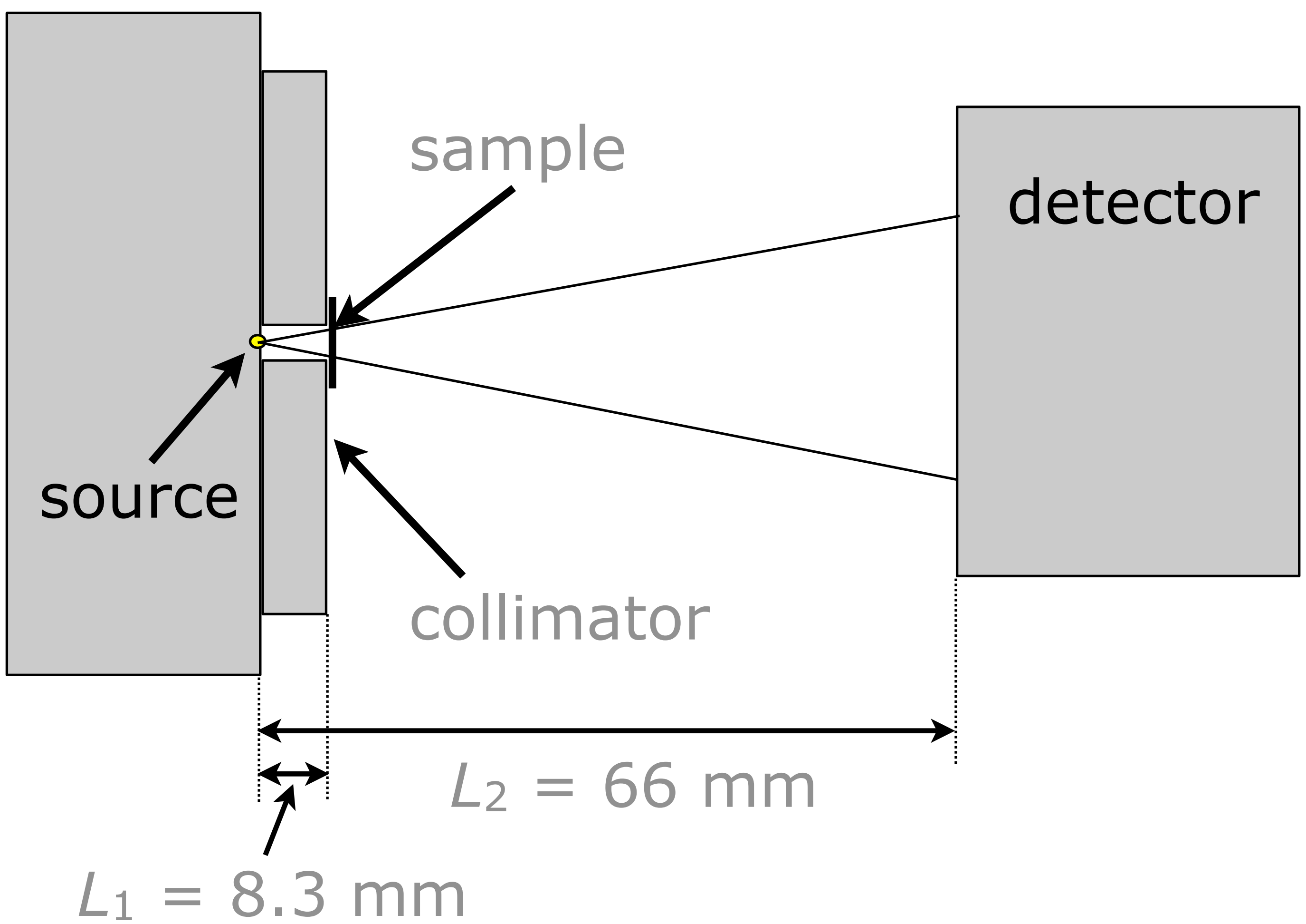
→ short optical path (40 - 70 mm)

Detector presented by Y. Houltz (SSC) and P. Wiklund (Scint-X)

Development Tests: Dec. 7, 2008

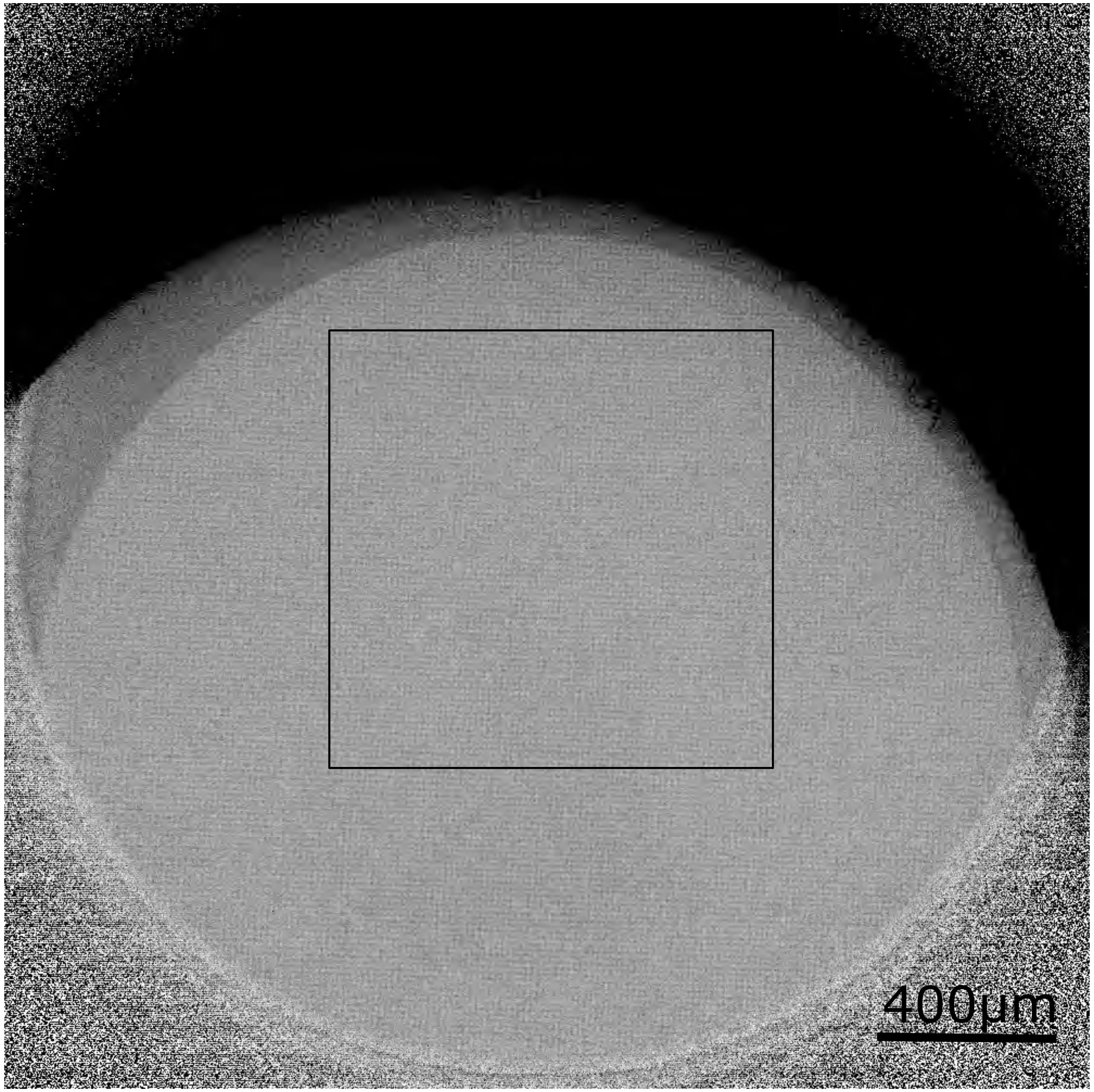
using:

- Viscom x-ray microfocus tube (technology demonstrator)
- Vosskühler camera with Scint-X scintillator



L_1: slightly larger
L_2: ~ design value

Development Tests: Dec. 7, 2008



Sample: 2000mesh
pitch: 12.7 µm
width of bars: 4 µm
thickness: ~ 5 µm

U = 60 kV, I = 50 µA
Source size: ~3 µm

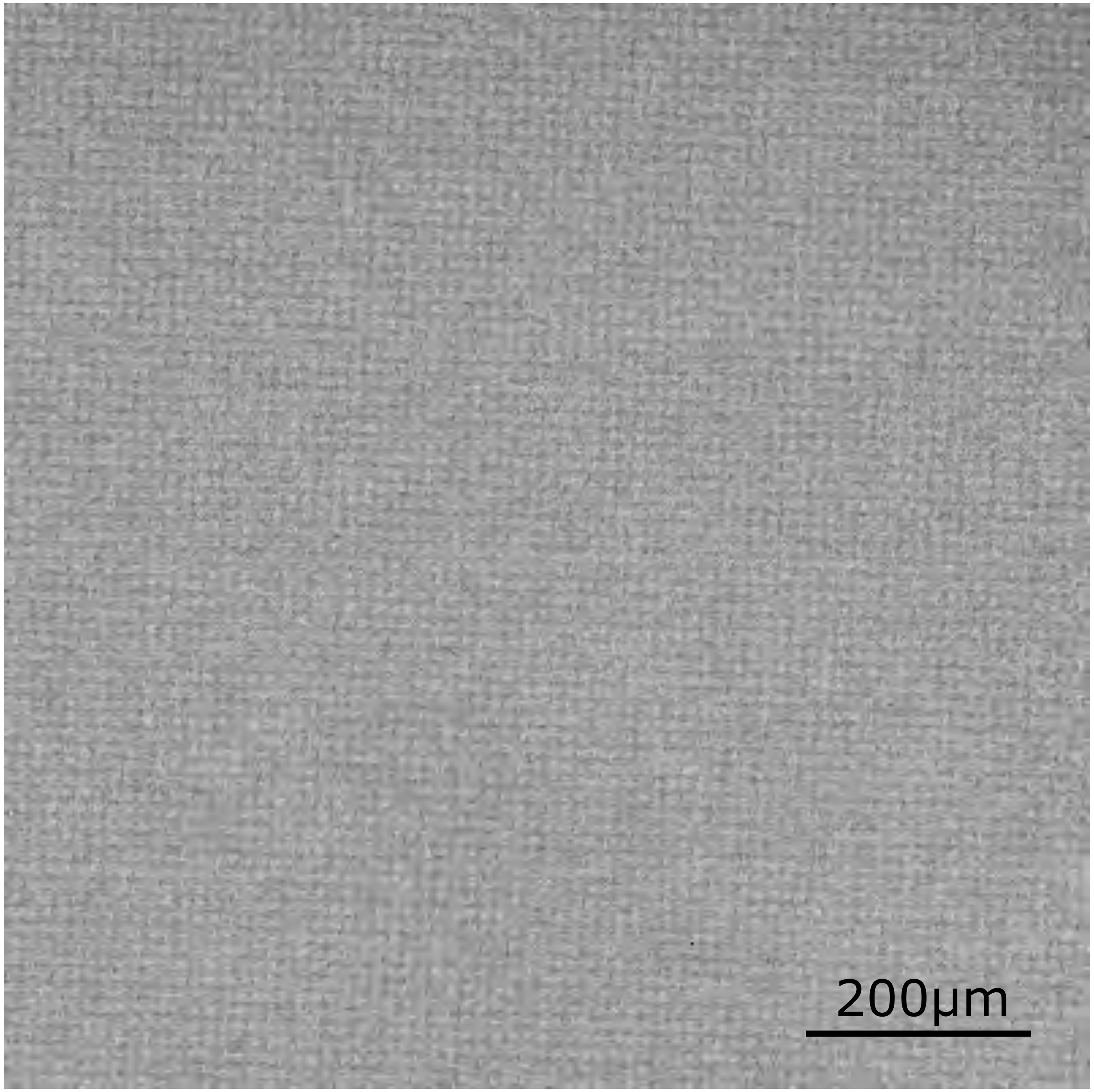
L_1 = 8.3 mm
L_2 = 66 mm

magn.: 7.86 x

exposure time: 0.997 s

eff. pixel size: 2.41 µm

Development Tests: Dec. 7, 2008



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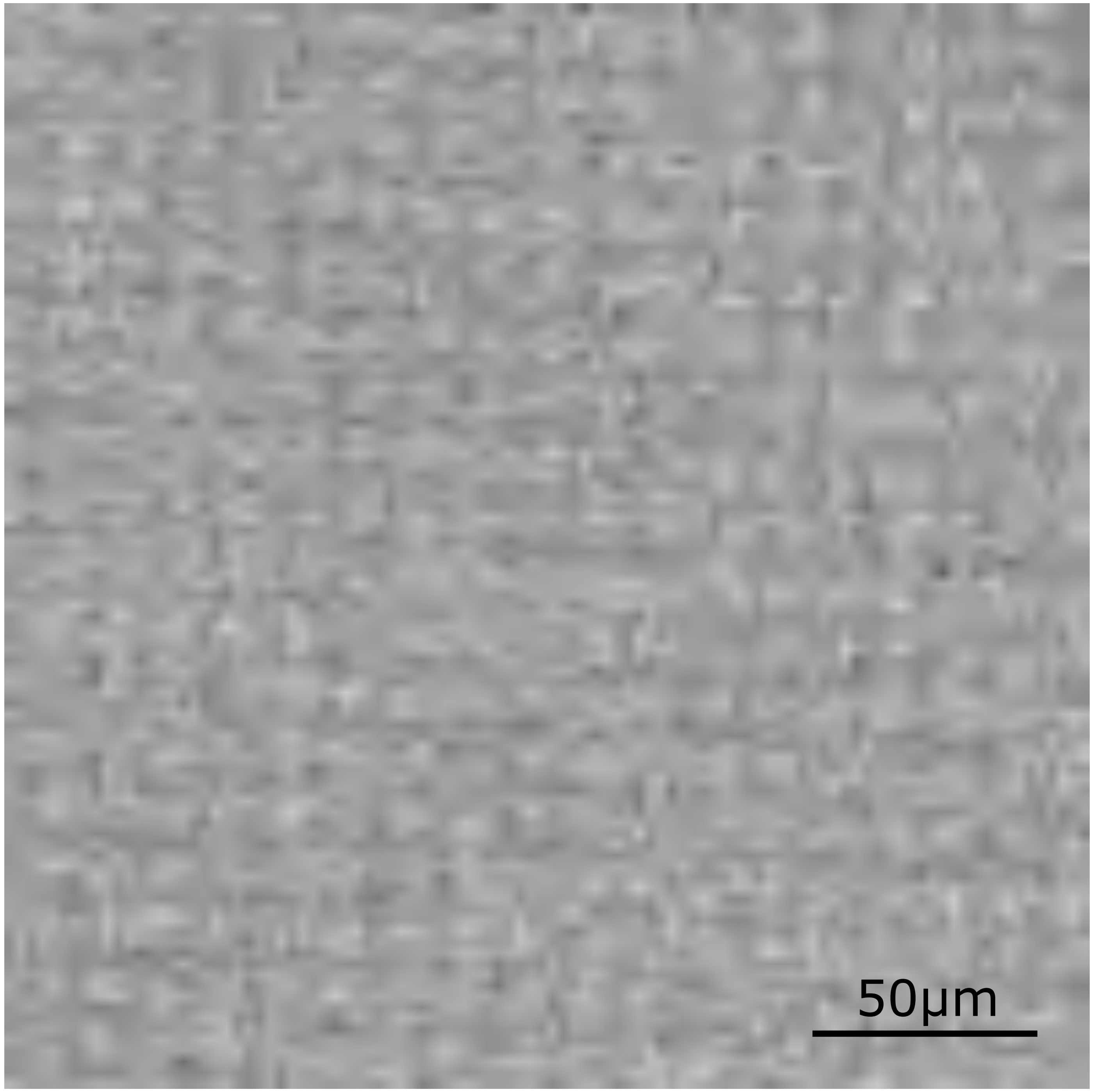

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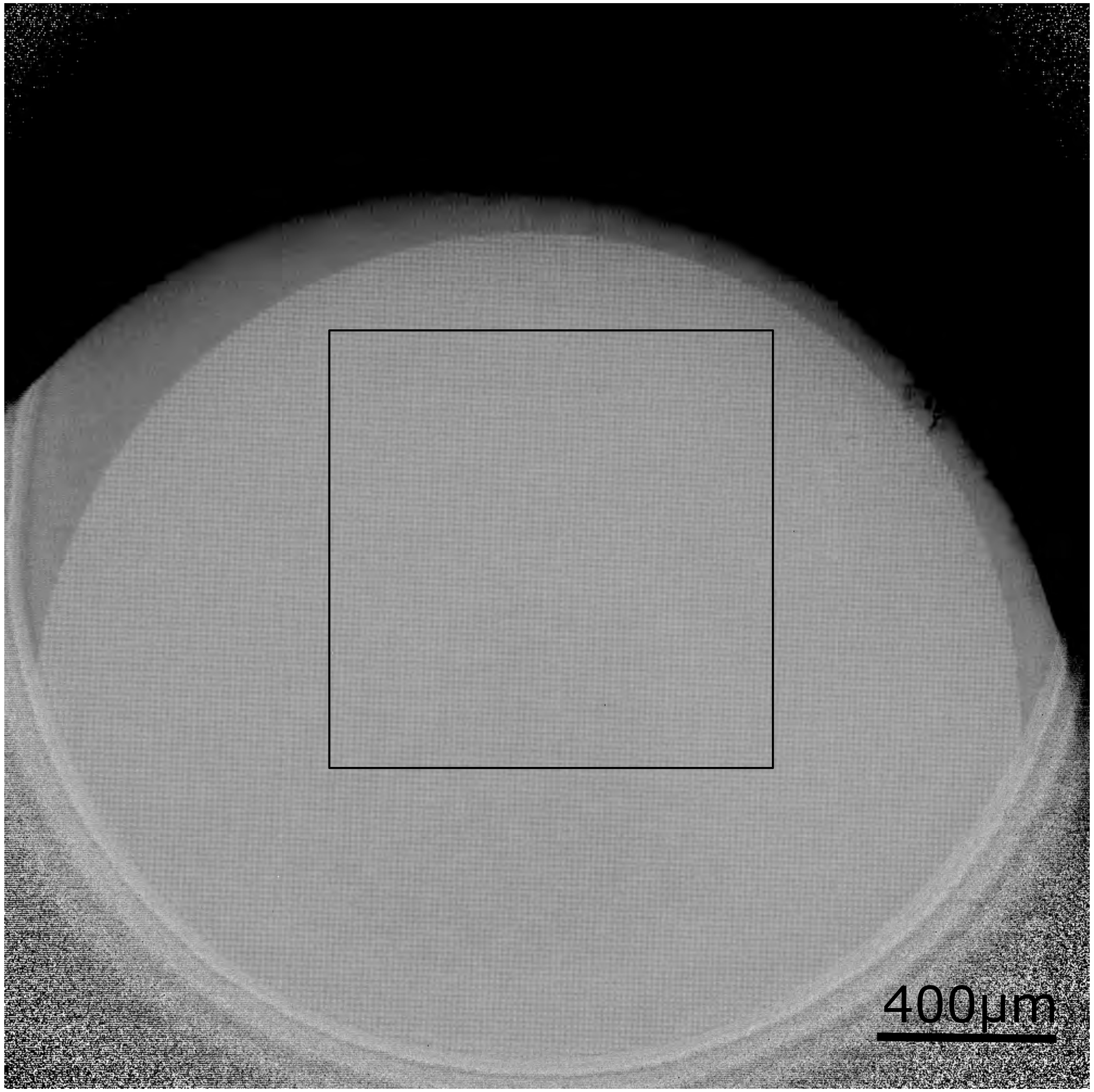

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Average 15 images!

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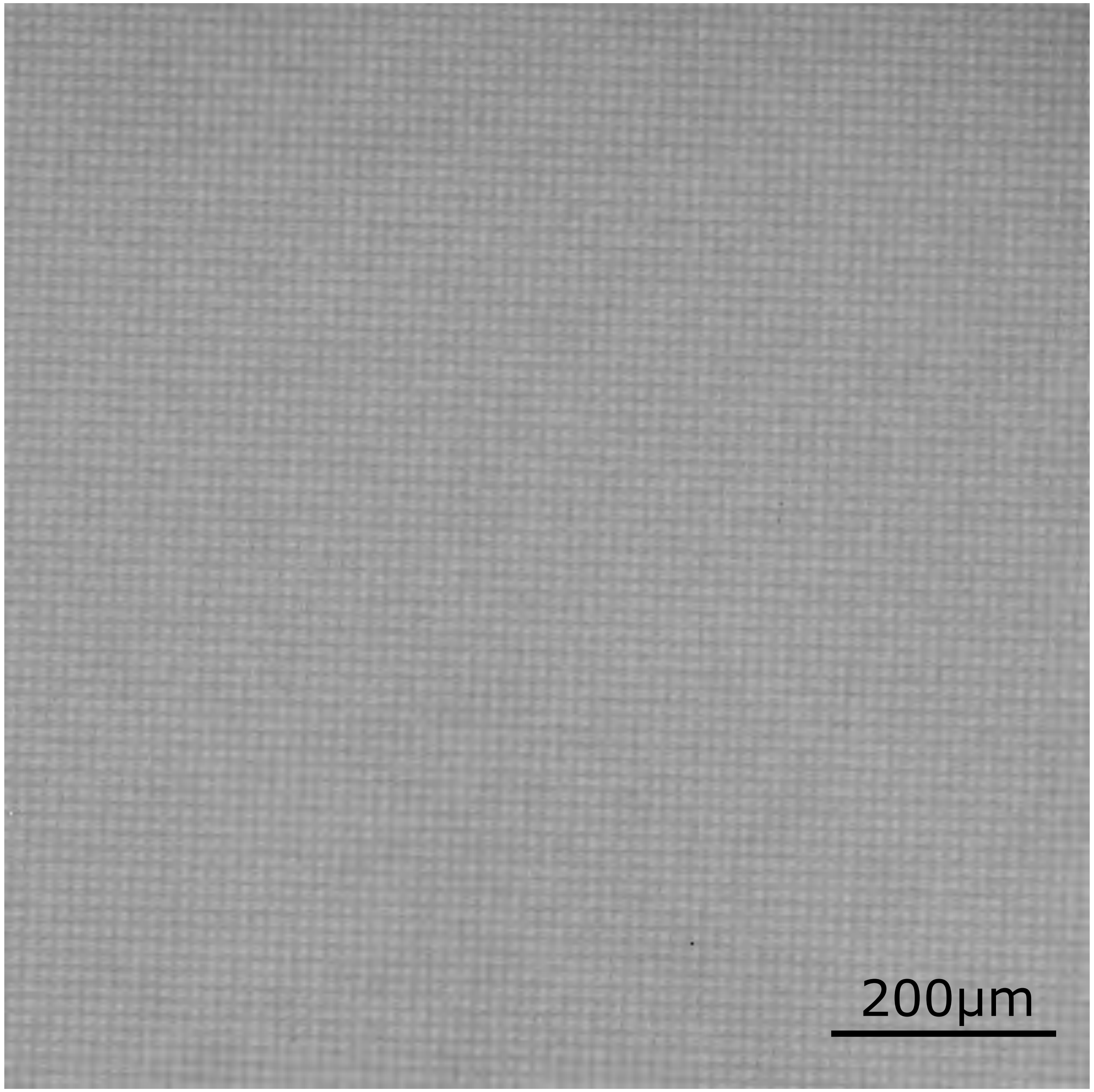

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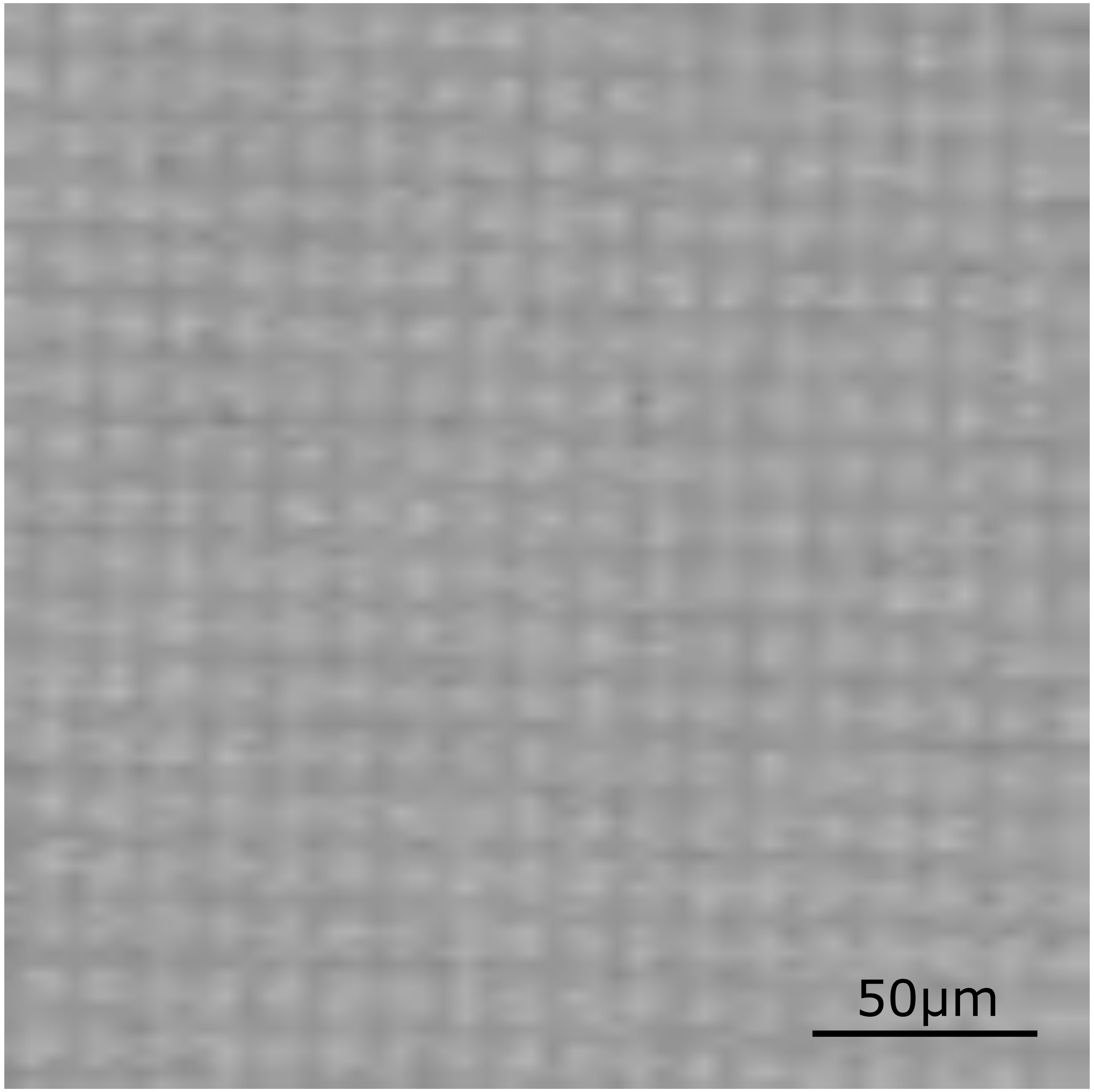

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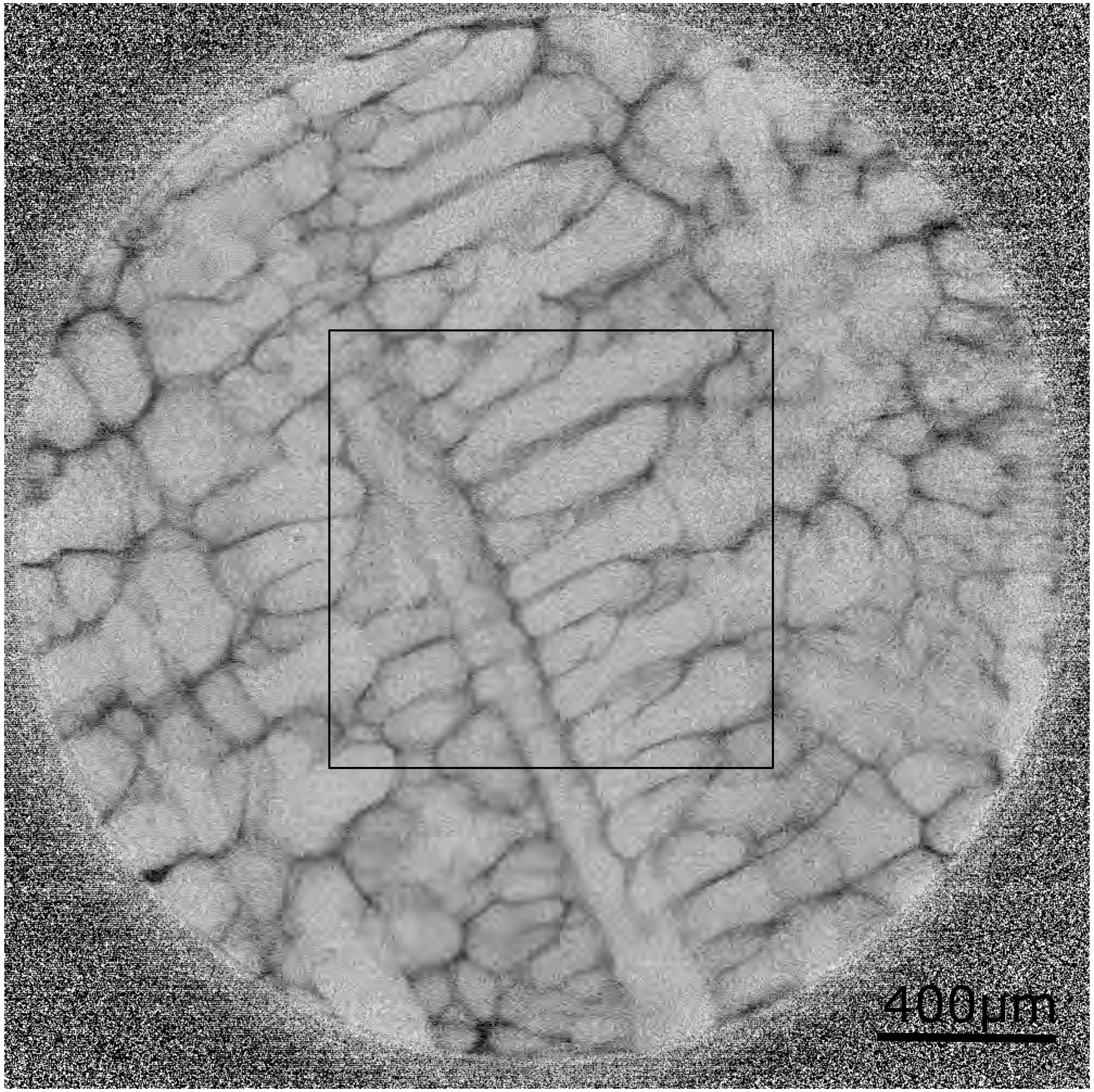

Sample from
R. Mathiesen
(thickness ~100 µm)

U = 60 kV, I = 50 µA
Source size: ~3 µm

L_1 = 8.3 mm
L_2 = 66 mm

magn.: 7.86 x

exposure time: 0.33 s

eff. pixel size: 2.41 µm

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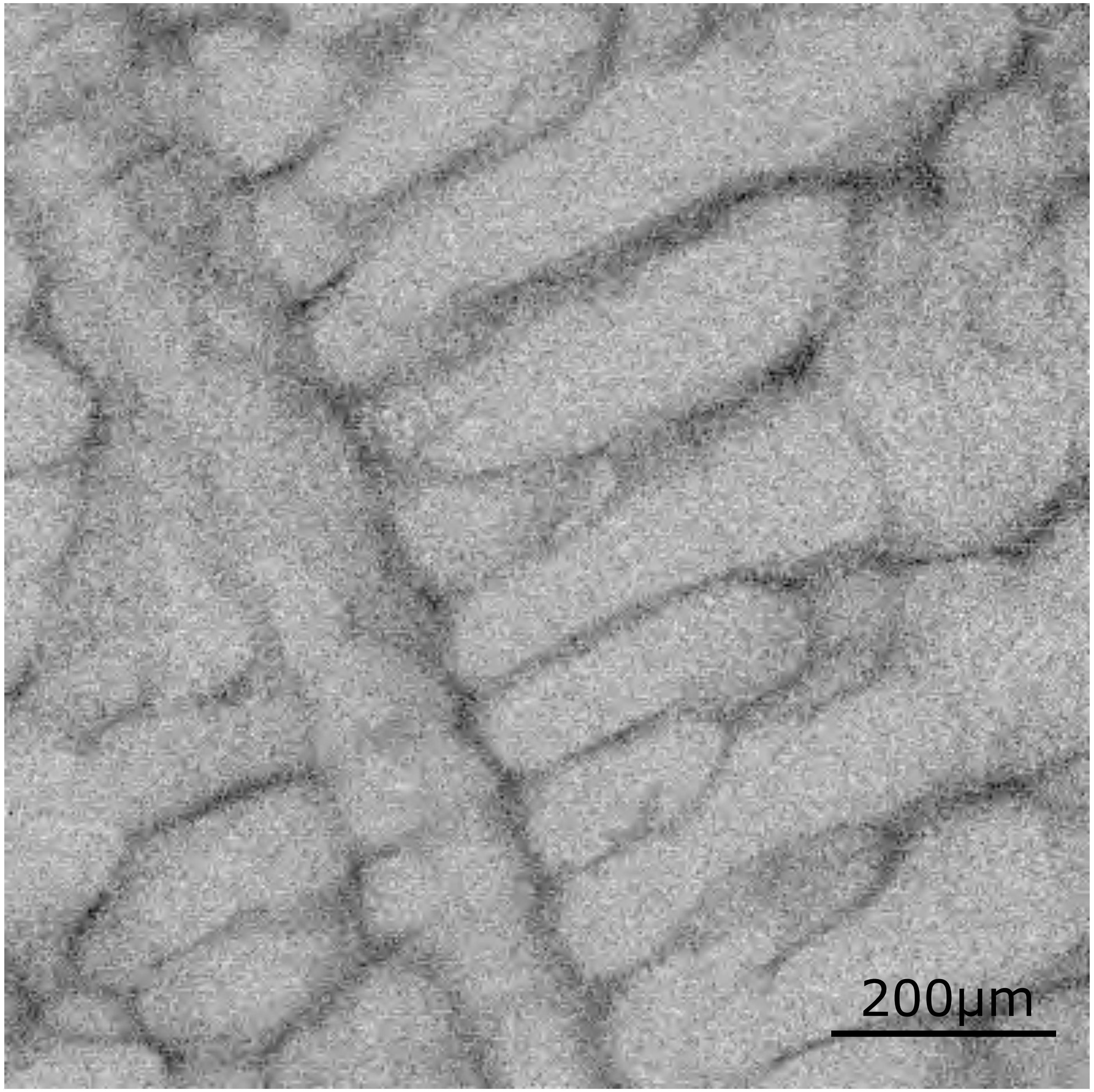

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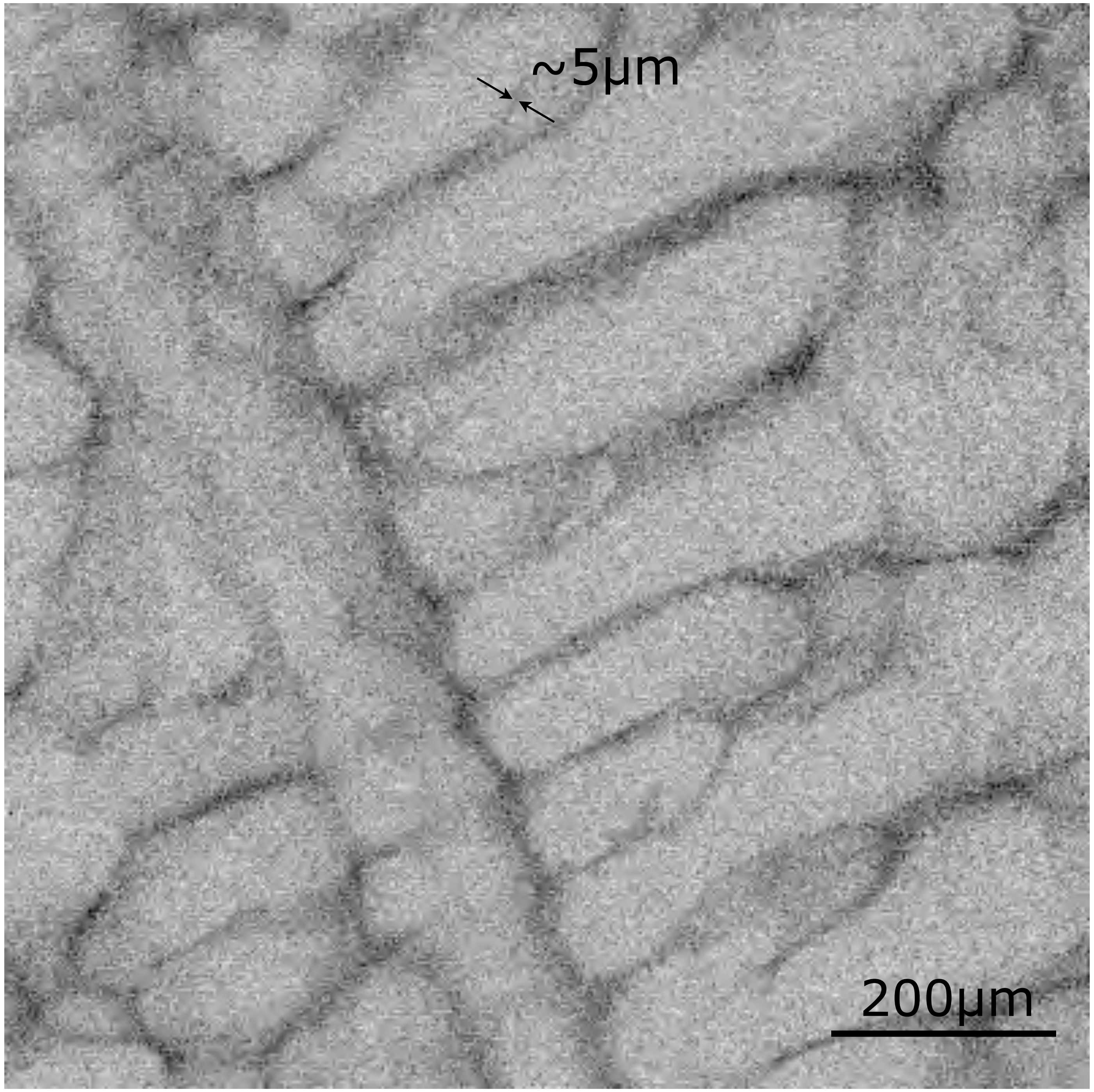

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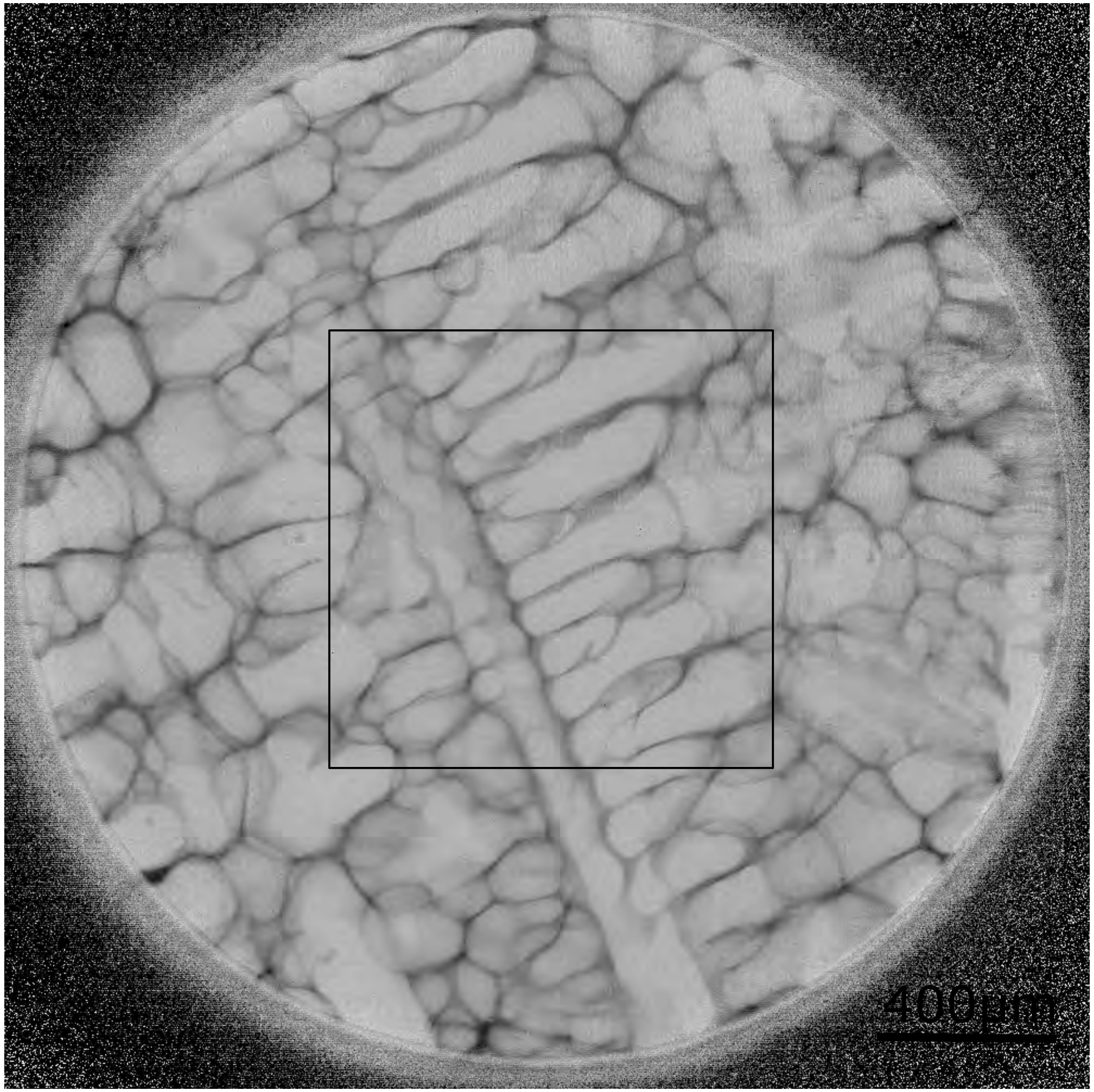

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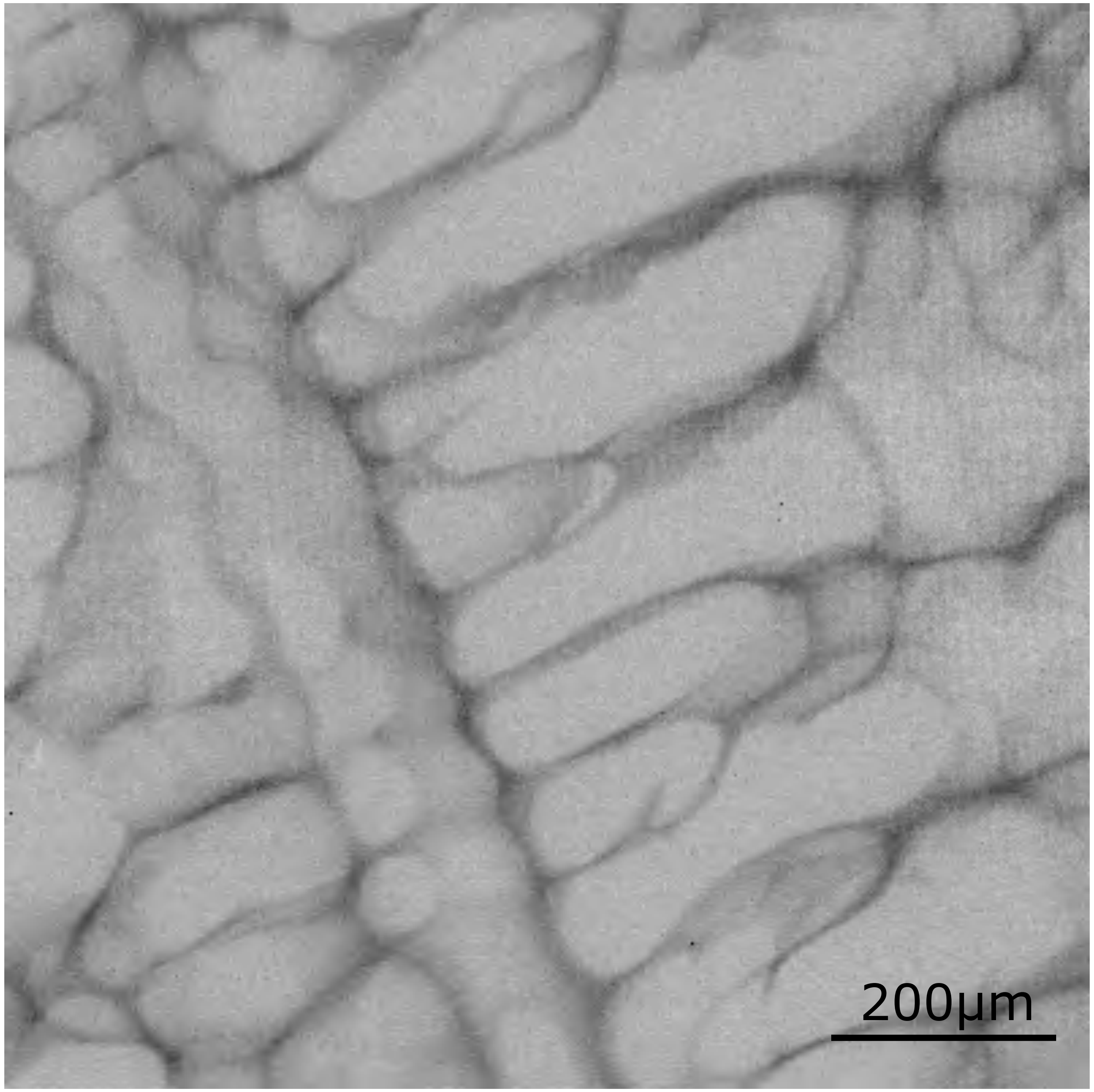
Average of 17 images!

Development Tests: Dec. 7, 2008



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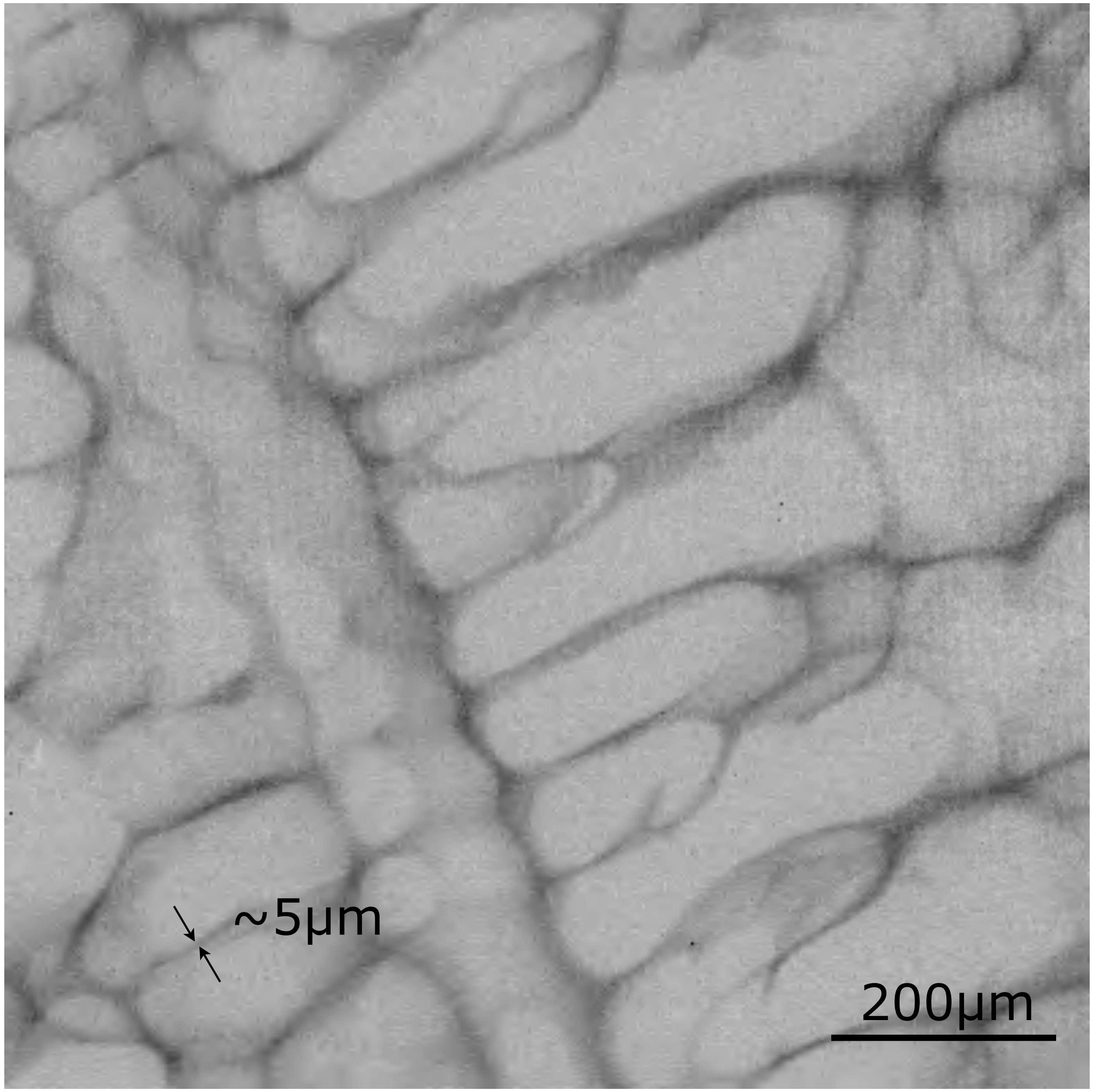

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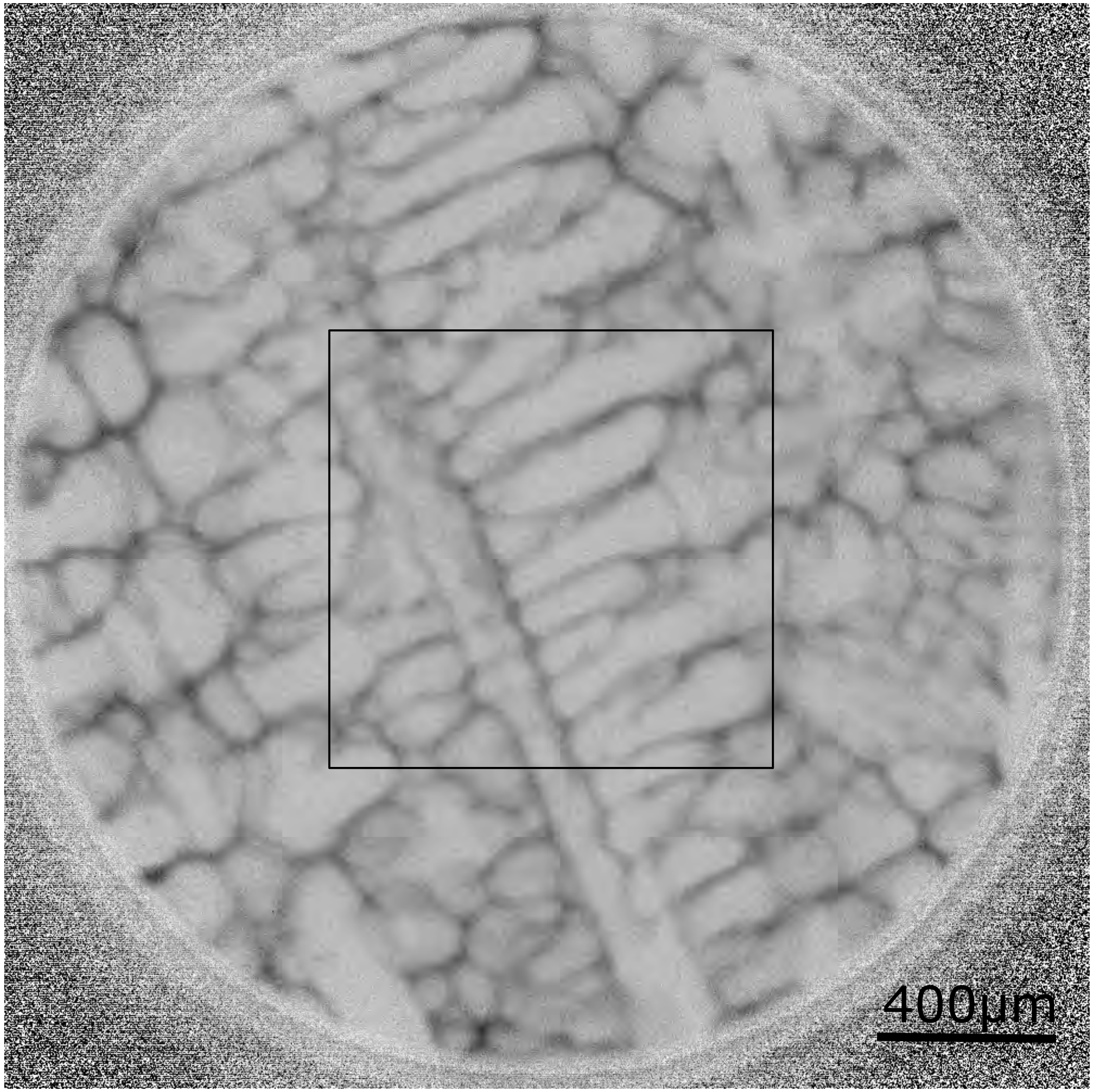


Sample from
R. Mathiesen
(thickness ~100 µm)

U = 60 kV, I = 200 µA

Source size: ~12 µm

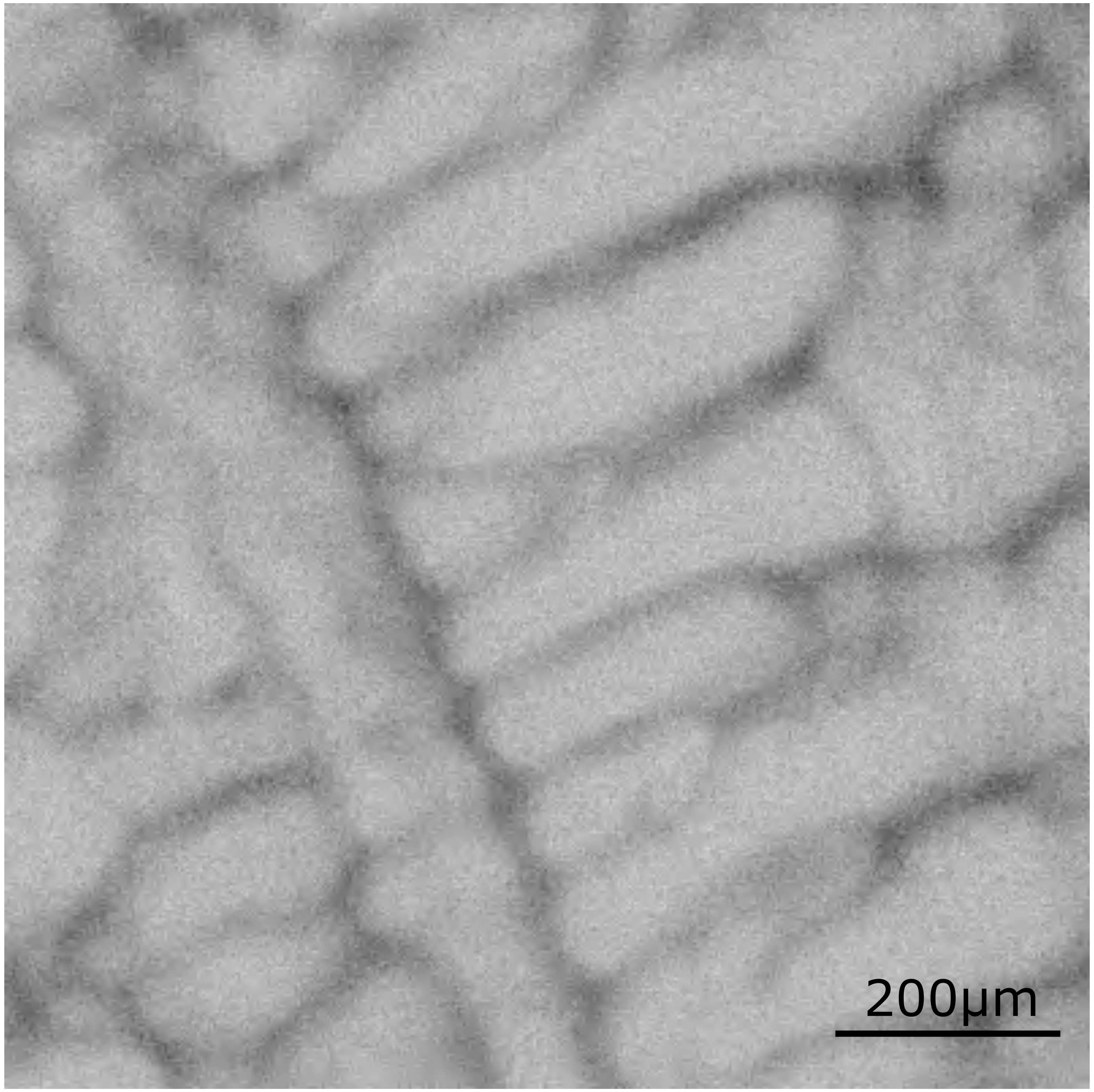
L_1 = 8.3 mm
L_2 = 66 mm

magn.: 7.86 x

exposure time: 0.33 s

eff. pixel size: 2.41 µm

Development Tests: Dec. 7, 2008



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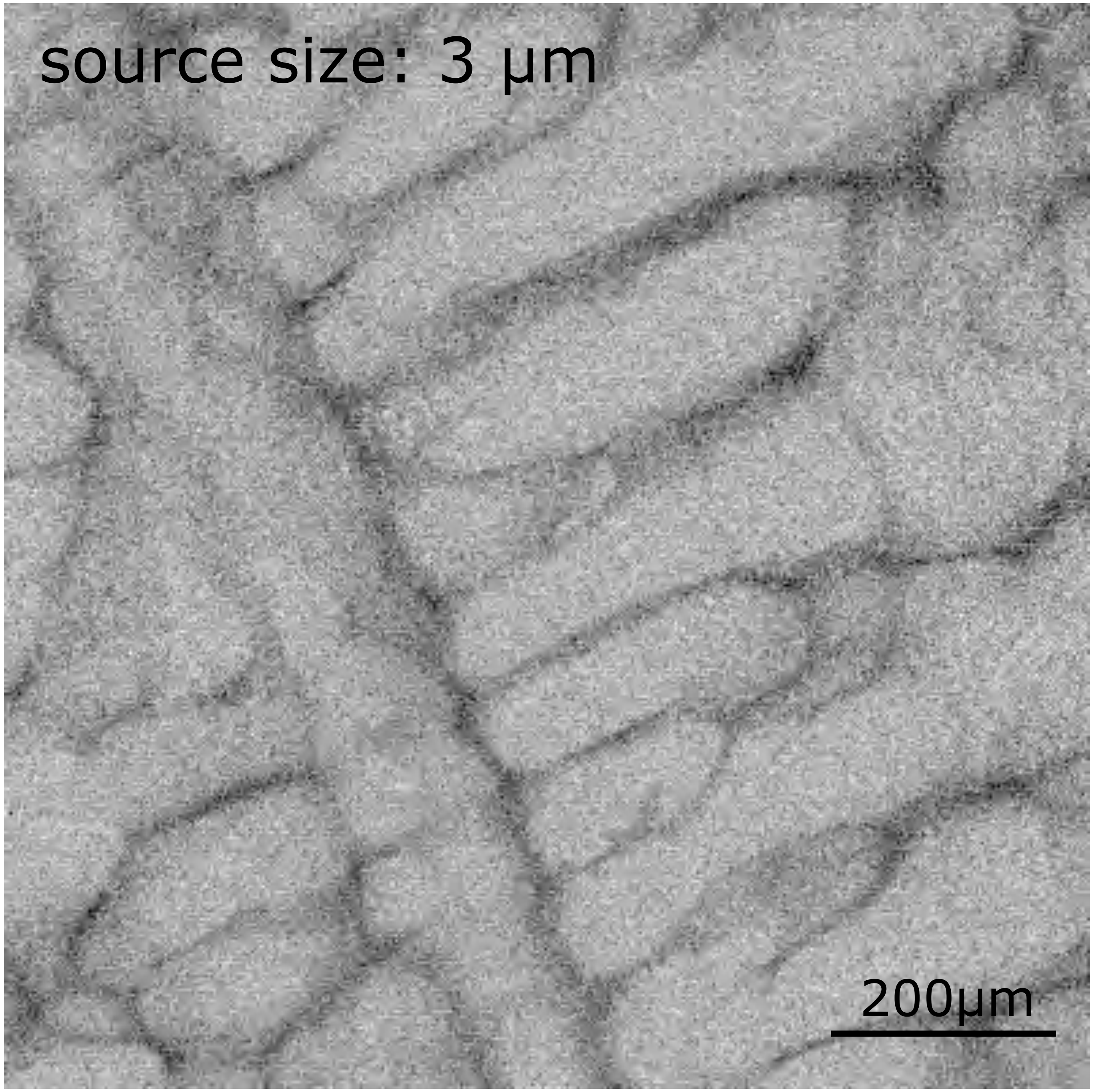

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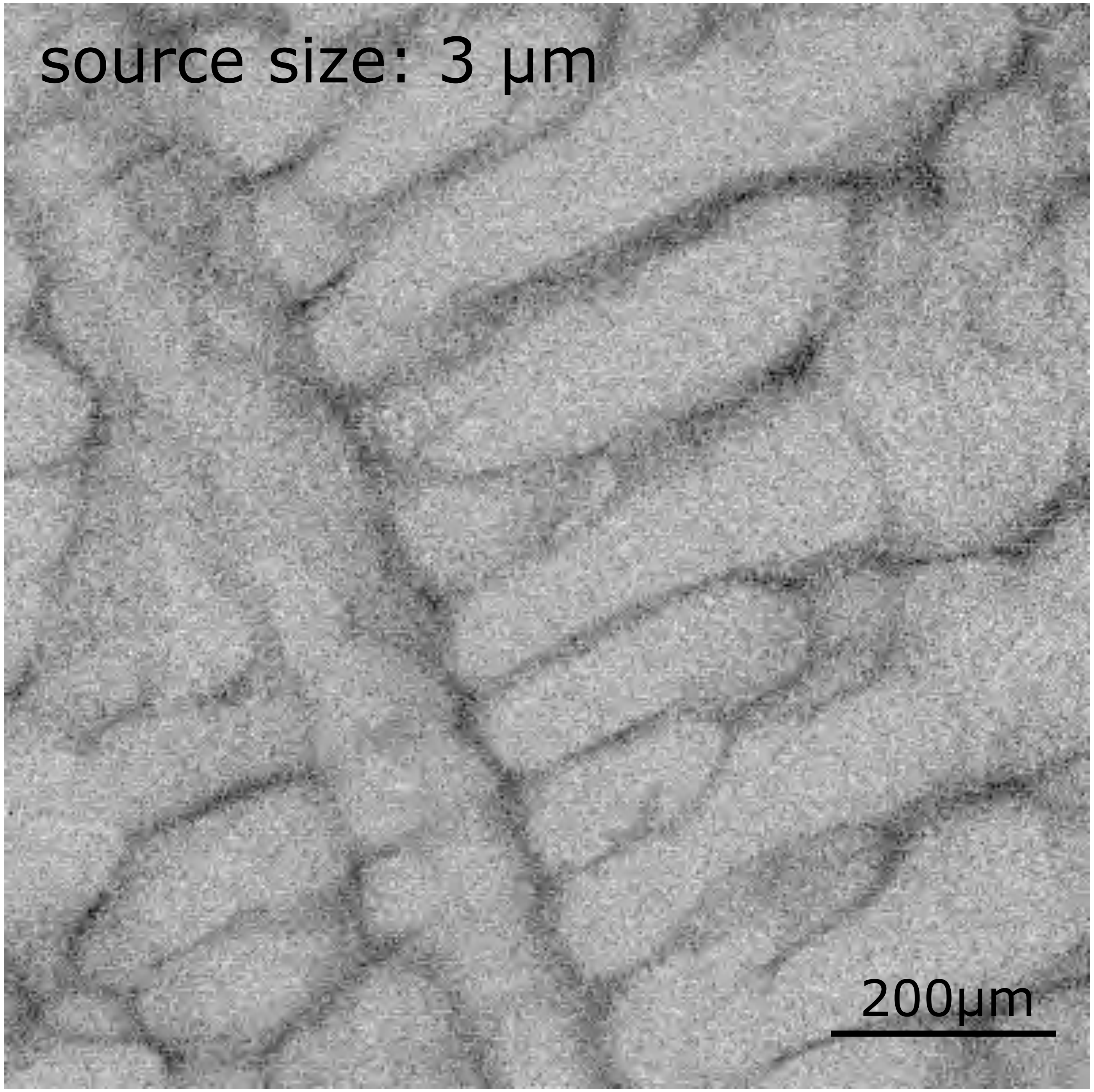

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Correct Geometry:

gain in Flux: ~2.45

Finalizing the Design

Today:

Design details to discuss:

- Front plate:
  - source point position vs. optical axis in furnace?
- mechanical support:
  - attach translation actuator to front plate of tube?
- inert-gas chamber:
  - evacuable to pre-vacuum (flushing)
  - electronic feed-through only (no mechanics)
  - camera outside of vacuum, kapton window at exit of chamber
- control system:
  - software interface to camera? (External control?)
  - frame-rate (2x2 binning) while saving data?